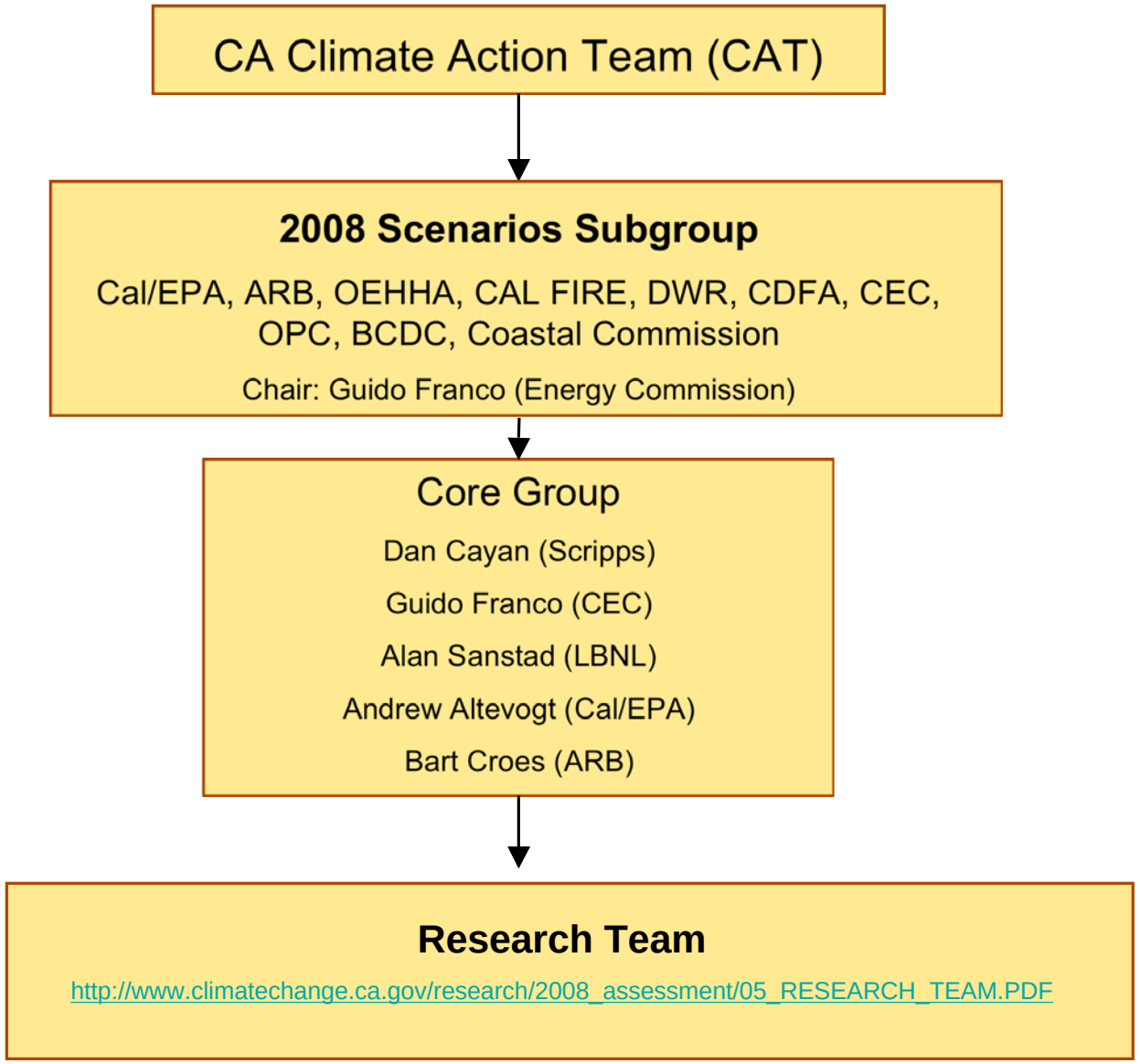
The 2008 Climate Change Impacts Assessment Organizational Flow



2008 Climate Change Impacts Assessment
Draft Overall Scope of Work

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Overview

The 2006 Climate Scenarios Report provided a valuable initial overview of climate impacts on key sectors in the state that are expected under alternative greenh ouse gas emission scenarios. The 2008 Climate Change Impacts Assessment will build on the 2006 Scenarios Report to meet three goals: 1) improve the assessment of climate changes in the California region and associated impacts on key physical and biological measures; 2) begin to translate these physical and biological impacts into sectoral economic impacts; and, 3) begin to develop and evaluate strategies for key sectors or regions for adapting to climate changes already underway.

To achieve these goals, the 2008 assessment will expand on the 2006 assessment in three ways:

1) *Refine the regional climate projections to more fully capture changes in variability and begin characterizing probabilistic climate changes.*
   Improving the approaches for downscaling results from global models to regional models and incorporating ensembles of climate projections will enhance our ability to characterize the changing risks to key hazards such as floods, droughts, wildfires, and heat waves. This analysis will be valuable for developing adaptation strategies. It will also be used to expand the treatment of risk and uncertainty in economic assessments of potential climate change impacts and adaptation options in California.

2) *Consider climate changes within the context of broader social changes, such as land-use changes and demographic shifts.*
   The 2006 assessment examined the impacts of climate changes with the assumption that, in general, all other factors remained constant. However, to evaluate the

[1] This draft document has also benefited by informal discussions between members of the core group with the following researchers: Tony Westerling (UC Merced), Brian O'Neil (IIASA and Brown University), John Battles (UC Berkeley); Larry Dale (LBNL), Doug Rotman (LLNL), and Lee Hannah (Conservation International and UC Santa Barbara).

economic impacts of climate change and develop strategies for adaptation, these impacts must be considered as part of a set of multiple stresses that are associated with the economic development patterns in the state.

3) *Consider climate change adaptation strategies both within and across sectoral boundaries.*
   The 2008 assessment will build on previous work to characterize the risks that climate change poses to California's natural resources, economy, and the public health. Although the state is identifying opportunities for reducing the emissions that cause global warming, some changes in climate conditions are inevitable. A number of initial efforts have been made to identify sector-specific adaptation strategies to projected biophysical changes (e.g. water management). The 2008 assessment will expand this area of work; however, many of California's adaptation challenges cross sectoral boundaries and are affected by a suite of changing socio-economic factors, including evolving climate change policies. We will begin to address this by drawing on the expertise of state planning and regulatory staff to develop case studies that reach across different natural and socio-economic sectors.

This draft scope of work is organized by area of research and represents our conceptual understanding of what could be done during a relatively short period beginning this summer, 2007 and completed in summer, 2008. Because this draft has not been circulated to the broader research community, it is possible that some of these items may be revised, and that additional topics may be identified.

Regional Climate Projections for California

We suggest that the 2008 assessment focus on the same global emission scenarios, global climate models and time horizon (through 2100) for projecting climate change impacts as the ones used in the 2006 Report. In addition, several global model simulations from upwards of 15 global climate models, available from the recent AR4 IPCC Assessment (4th Climate Change Assessment of the International Panel on Climate Change), will be used to provide an ensemble of temperature, precipitation and other climate variables for the California region. These simulations, and a downscaled version of some of them, will be made available to the team of researchers for impact modeling. For the impact groups with models that are sufficiently flexible and efficient to generate a suite of runs from a large set of input runs, this will be a significant step in developing probabilistic impact assessments.

Two new PIER projects starting in the near future may provide additional information in the development of initial estimation of probabilities of the different climate scenarios. The first project, conducted by Dr. Tom Wigley from NCAR, will assess how well global climate models simulate the transport of moisture from the Pacific Ocean to the California region. Transport of moisture from the Pacific Ocean is a key factor in determining precipitation levels in the Western United States. The second project, headed by Prof. Steve Schneider from Stanford, will deal with the issue of probability of future global climate forcing scenarios.

PIER researchers are comparing the simulation of dynamic and statistical regional climate models with historical meteorological data (inter-comparison project). They are assessing the different downscaling methods to determine how well these models can simulate past climatic conditions in California given "perfect" boundary conditions (i.e., boundary conditions from re-analyses). The evaluation will determine if biases are present, and how they might need to be adjusted when the models are used to project future climatic conditions in California.

To attain the needed spatial resolution of the key input climate drivers in the 2008 assessment, we propose to use statistical downscaling models and to conduct an inter-comparison study that will be part of or at least coordinated with the inter-comparison work described above. Because time, computer resources, and funding are limited, for the 2008 report we do not plan to use numerical/dynamic regional climate models but will instead rely almost exclusively on the less computationally-expensive statistical schemes to downscale the global climate model output. To allow for meaningful inter-comparison, the statistical models should use a common period for model calibration and a different common period for model validation. Special attention should be paid to the simulation of extreme events.

Further work will be carried out on climate change detection to determine if changes in climate and hydrologic measures such as temperature, frost days, snowpack, and timing of runoff that have been observed in the California region can be attributed to natural variability; if not, these changes will be investigated to determine if they are consistent with climate changes expected from greenhouse warming.

Products:

- Data sets of the different climate scenarios to be used for impact/adaptation studies
- A paper on the simulation of transport of moisture from the Pacific Ocean to the Western United States.
- A paper on the probability of climate forcing (One probability distribution for the "business as usual" case and another that assumes rapid and drastic global emission reduction compatible with the Framework Convention on climate change)
- A paper on the regional model inter-comparison work
- A paper on climate and sea level scenarios.
- A paper describing flood mechanisms and changes in flood frequency of coastal and Sierra watersheds, including an evaluation of atmospheric circulation changes
- A paper on climate change detection and attribution

Development of Socio-economic and Urban Growth Projections for California

The 2003 PIER report on climate change demonstrated the importance of considering potential socio-economic changes in California when conducting climate change studies

(CEC 2003). For this task, we will develop socio-economic scenarios for California that are compatible with the SRES (A1, A2, and B1) global emission scenarios. These scenarios will also be compatible with available California-specific forecasts of key variables, such as statewide population, economic growth, and broad demographic cohort profiles. A starting point for this work will be the simple socio-economic scenarios developed for the 2003 PIER report (Wilson 2000).

There are several options for building upon previous and current work. The U.S. EPA is funding the creation of a national (U.S.) set of socio-economic scenarios "downscaled" from the SRES scenario and generally analogous to the customization of the scenarios recently developed by IIASA for the A2, A1, and B1 scenarios with a 0.5 to 0.5 degrees resolution (Grübler et al. 2006). For micro-scale projections, we could also build on the GIS projections of California urban growth developed by Prof. John Landis for the 2003 report (Landis 2003)
To maximize the applicability of the scenarios to economic impact analyses in the selected sectors, we will concentrate the detailed scenario effort on projections of those variables and factors – such as energy prices – that are of greatest importance in assessing potential impact costs and adaptation benefits.

Products:

- A paper on socio-economic scenarios for California
- A paper on urban, suburban, and exurban scenarios for California

Impacts on Water Resources and Potential Coping/Adaptation Strategies

UC Davis has developed an optimization model (CALVIN) of the water system in California. CALVIN assumes ideal water markets and perfect foresight. For this reason, the costs provided by CALVIN should be taken as lower-bound values. Researchers at UC Davis are improving the model's consideration of features such as sea level rise and the need to supply additional water to the Delta to maintain the quality of the water exported to Southern California. They are also improving the representation of groundwater resources that past studies suggest would be an important tool to ameliorate the negative effects of climate change.

The CALVIN model will be used to identify potential coping strategies. The model could also be used with more restrictive water markets and with limited foresight. This exercise would be useful to explore options that are, perhaps, more politically acceptable while at the same time do not deviate too far from the optimum solutions.

UC Berkeley and the Stockholm Environmental Institute (SEI) used the WEAP[2] model for the 2006 assessment to study the potential impacts of climate change on water

[2] SEI's Water Evaluation and Planning Tool (WEAP)© is a microcomputer simulation tool for integrated water resources planning. It provides a comprehensive, flexible and user-friendly framework for policy analysis.

resources in the Sacramento Valley. They will start a project for PIER in the next few months designed to enhance the WEAP model to allow simulations of conditions in the San Joaquin Valley (east portion of the Valley). For the 2008 report, SEI and UC Berkeley will conduct a similar study for both the Sacramento and San Joaquin Valleys. The model could be used to investigate coping strategies (e.g., relaxing some of the current water rules) or could be used to investigate some of the coping strategies suggested by CALVIN.

The California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) are conducting a follow-up study to the work they did for the 2006 report. They are using the CALSIM water resources simulation model for this study. Since CALSIM assumes that existing water rules apply in the future even under very different climate regimes, the estimated costs reported by this model may represent upper-bound estimates. A large set of runs of the CALSIM model will be used to investigate climate impacts on California's large, complex river basins. These CALSIM model runs will use input from the ensemble of climate change simulations, downscaled over the California region, as discussed in the Climate Scenarios section. Mike Dettinger from the USGS and the UCSD Scripps Institution of Oceanography (Scripps) will provide guidance on how to convert the limited set of simulations into a probability distribution of impacts. This work could be seen as a prototype for future PIER impact/adaptation studies

An additional study will be undertaken to integrate the cost estimates provided by CALVIN, WEAP, and CALSIM and to consider other on-going studies such as the study being conducted for DWR on potential failures of the Delta Levee system. Additional new economic analysis would also be welcome. PIER will submit a request for proposals to all the economic departments of major universities in California for this work.

Products:

- A paper reporting results from CALVIN
- A paper reporting results from WEAP
- A paper from DWR, USBR, and Scripps on the probability of different impact levels using CALSIM
- A paper on overall economic impacts for the water sector

Agricultural Impacts and Potential Coping Strategies

We will use a process-based crop model to estimate how climate change may affect important crops in California. We will most likely work with Prof. Johan Six (UC Davis), given the fact that his group have already performed several studies for PIER simulating historical conditions using two different crop models (DNDC and DayCent) for California. This project would also involve the use of recently developed statistical relationships between weather and crop yields in California (Lobell, 2006).

To investigate economic consequences of potential agricultural impacts, we are considering a request for proposals to agricultural and resource economics departments in

major universities in California. The ideal situation would be to find an economist that is already interacting with crop modelers and that could easily translate the crop modeling results into economic impacts to farmers and consumers. The same economist(s) would need to try to incorporate the work done using CALVIN and WEAP into the economic evaluation[3]. The main advantage of using CALVIN and WEAP is that these models also take into account water scarcity, whereas a disadvantage may be their relatively simple representation of the agricultural sector.

One interesting option is to ask the economist to consider the potential revenues that may be available to farmers if they are allowed to participate in a market for greenhouse gas (GHG) credits. Results from a PIER project with UC Davis/Kearney Foundation will be available in the fall of 2007 and will show, in a GIS format, the opportunities to reduce GHG emissions at the parcel level for several important agricultural counties in California.

The economic evaluations must make use of new estimates of elasticities of demand being developed by economists at UC Davis for agricultural products for the Department of Food and Agriculture.

The economic impacts on the agricultural sector is another impact category in which expanded treatment of risk and uncertainty may be possible using probabilistic climate information and sufficiently flexible economic models. In addition, we will assess the possibility of improved analysis of technological change affecting agricultural productivity. Contrasting assumptions in these two categories are responsible for a considerable part of the wide variation of estimates in previous economic studies of climate change impacts on North American agriculture. The researchers will explore different coping/adaptation strategies such as changes of cropping patterns in time and space.

Products:

- A paper on changes in agricultural yields using process-based crop models
- A paper on impacts on agricultural yields using statistical crop models
- A paper on overall economic impacts to the agricultural sector. This paper will also discuss and quantify potential coping strategies.

Coastal Impacts and Potential Coping Strategies

DWR is funding a study of the potential collapse of the Delta levee system and USGS is conducting a study for CALFED on the impact of climate change in the Delta. We will use the results of these studies as much as possible.

PIER has just started a new project with the University of Florida and Scripps designed to develop and apply a new coastal evolution model for California. One of the first

[3] Both the CALVIN and the WEAP models estimate potential economic impacts to the agricultural sector, but use different approaches.

technical tasks under this contract is the use of the SWAN model to identify erosional "hotspots." The SWAN model is a refraction-diffraction model designed to predict coastal wave energy delivery and to estimate alongshore sediment transport fluxes. This project will allow us to identify regions that are likely to witness beach depletion or accretion for a series of given wave conditions. Understanding beach behavior is extremely important in determining coastal evolution, as beaches buffer sea cliffs from wave attack. The researchers will use the detailed sea level scenarios developed by Scripps for this study. This study will most likely focus on Southern California.

With funding from PIER, Scripps/USGS is also performing a study of the San Francisco Bay Delta region to identify areas that would be inundated under different sea level scenarios. Dr. Noah Knowles of USGS presented some preliminary results at the Third Annual Research Conference on Climate Change and at the 4th Biennial CALFED Science Conference. This work is being coordinated with the San Francisco Bay Conservation and Development Commission (BCDC). Drs. Knowles, M. Dettinger, P. Bromirski and Cayan and their collaborators will enhance this work to consider the combined effect of sea-level rise and fresh water flood flows from the relevant Sierra watersheds.

Climate-induced sea-level rise will put coastal areas, such as the San Francisco Bay and the connected Sacramento/San Joaquin Delta, at tremendous risk of flooding. A number of national studies on the economic cost of sea-level rise suggest that, while adapting to climate change will be expensive, substantial investments are already at risk and vulnerable. Because the economic costs of flooding are highly site-specific, regional analyses are critical for guiding land-use decisions and evaluating adaptive strategies. Dr. Peter Gleick will update a study he conducted in 1990 of the San Francisco Bay using new scientific and socio-economic information and will also consider market-driven responses to sea-level rise, such as depreciation of coastal property at risk of inundation.

Under this task we will also release a RFP to request proposals from universities and consultants to update and enhance the 2003 PIER report on the potential economic costs of sea level rise on open ocean coastal properties in California (Newman 2003). Some of the deficiencies that need to be addressed in the new study include: 1) consideration of ecological impacts; 2) more realistic simulation of social responses to sea level rise; and 3) indirect effects of coastal protection.

We may also want to pursue research on the economics of coastal impacts that deal explicitly with extreme events arising from the confluence of sea level rise, storm surges, coastal development, and other factors. These "low-probability, high-consequence" events may characterize the economic risks of coastal impacts in California.

Products:

- A paper on the identification of coastal hot-spots in Southern California vulnerable to sea level rise

- A paper on vulnerability of the San Francisco Bay Delta to inundation from oceanic surges, sea level rise and fresh water flood flows from Sierra watersheds
- A paper on economic impacts and adaptation options for the San Francisco Bay.
- A paper on overall economic costs to this sector. This paper will also include discussion of potential coping/adaptation strategies.

Public Health

It will be necessary to update the literature reviews of the 2006 scenarios report to reflect the latest research on direct public health impacts of climate change. This will be done by ARB and OEHHA staff.

PIER has funded retrospective analysis studies with OEHHA and Harvard University on the impact of temperature on public health (e.g., heat-related deaths). These time series and case-crossover studies of California counties attempt to separate the effects of temperature from air pollution on daily mortality, since some of the deaths attributed to high temperatures may be confounded by elevated air pollution levels. This work will be completed by early 2007 and results should be available for the 2008 report. OEHHA will perform additional analyses for the 2008 report, including: (1) determination of subgroups that are more susceptible to mortality effects; (2) analysis of 2006 heat wave and (3) analysis of relationship between temperature and hospital admissions.

ARB will fund Hayhoe et al. to significantly expand their previous work by adding two cities, including projected demographic changes, and applying the technique of Spatial Synoptic Modeling to the SERES scenarios. In addition, the proposed work will be able to estimate the impact of heat emergency action plans in preventing heat-related deaths.

The 2008 report will, to extent possible, estimate the economic costs associated with public health impacts of climate change. It is not possible to make credible estimates of the number of cases for most health impacts, particularly since society will not be willing to allow these impacts to go unchecked. It will, however, be possible to make estimates of the additional costs that will be needed by various public health programs to prevent health impacts. Examples of this include: costs for development and implementation of heat emergency action plans; and costs associated with expansion of vector control programs, increased electricity generation, additional water and sewage treatment, and fire fighting and prevention (including costs related to personnel, equipment and supplies) as California evaluates mitigation strategies to minimize the impacts of increased temperatures on all sectors of the economy. These calculations will be done by ARB staff. If contractors are able to calculate how many extra tons of GHG emission reductions are needed to reduce the risk of extreme events, ARB staff will calculate the extra mitigation costs associated with the additional reductions.

A companion analysis, focusing on historical observations, of the climatic patterns and trends leading to the July 2006 heat wave is being undertaken by A. Gershunov and D. Cayan at Scripps. This study may be included in the heat wave assessment.

Products:

- A critical review paper on public health and climate change
- A paper by OEHHA on high temperatures and human mortality and morbidity
- A paper by Hayhoe et al. on human mortality and morbidity and the impact of the implementation of emergency plans
- Overall public health economic impacts
- An evaluation of climatic factors associated with the occurrence of extreme temperatures during the July 2006 heat wave in California and the western United States.

Air Quality

It has long been recognized that climate conditions directly affect many aspects of ozone and PM formation. Thus, development of policies that integrate both air quality and climate goals is needed. These policies must be based on findings of scientific research projects that accurately incorporate and account for interactions between atmospheric composition and climate on global to regional scales. ARB and U.S. EPA have recently funded several research contracts to assess the consequences of climate change for air quality in California. Researchers at OEHHA are also studying the possible synergistic impact of air pollution and temperature (effect modification).

The interactions between climate change and regional air quality are of considerable interest to the research and policy communities. California is aggressively pursuing improvements in air quality through emission controls targeted at particulate matter (PM) and ozone. However, these pollutants also affect climate in important and complicated ways and climate change, in turn, could have large impacts on regional air quality. While it is expected that within one to two decades California airsheds will achieve conformity with the Federal (and potentially State) air quality standards for ozone and PM, this likelihood is based upon modeling scenarios relying on past and current climate conditions in California.

An ARB-sponsored research project with Mike Kleeman of UC Davis seeks to identify linkages between climate and air quality for major airsheds in California. In Phase I of the project, a detailed perturbation analysis was carried out to study the effect of meteorology and background concentrations of ozone and PM2.5 concentrations during present-day air pollution events. Changes to emissions inventories through population expansion, application of emissions control programs, interaction between future temperature and future emissions, further changes to background pollutant concentrations, and changes to the frequency and duration of stagnation events were not considered. Phase II of the current project will address some of these issues using dynamically downscaled meteorology combined with detailed air quality modeling. This modeling will include the development of a future emissions inventory in the years 2018 and 2030 (U.S. EPA funded research contract with UC Davis) for the San Joaquin Valley Air Basin (SJVAB) and 2020 for the South Coast Air Basin (SoCAB). The sensitivity of ozone and PM concentrations to nitrogen oxide (NOX), volatile organic compound

(VOC), and ammonia (NH3) controls will be studied in the SJVAB and SoCAB under future climate scenarios using the emission inventories and meteorological predictions derived from the Phase I and Phase II model simulations

A study that has recently begun by S. Iacobellis and D. Cayan of Scripps endeavors to better understand how the frequency and intensity of low-level temperature inversions have varied historically, and how these characteristics might vary or change in California in a changing climate. Particular emphasis will be placed upon the SJVAB and SoCAB. Part I of the project will examine historical climate records, regional model output, the Scripps Single-Column Model (SCM) model output, and reanalysis data from the past 50 years to characterize the variability of low-level inversions in California. The data will be analyzed on timescales ranging from diurnal to decadal. The UC San Diego investigators have also been collaborating with Drs. Michael Kleeman and ShuHua Chen of UC Davis. The UC Davis investigators will perform air quality model simulations of specific air pollution episodes at very high resolution (~1 km or less) in a limited number of historical and projected climate change periods.

Drawing from the above studies' findings, the UC San Diego investigators will compare the regional, and SCM model results for the same episodes with their results, and use the greater detail from UC Davis air quality modeling results, along with their insights, to better focus and meet overall objectives of this research project.

The second part of the project will use the Part I results and GCM runs to project the frequency and intensity of low-level inversions in future climate scenarios. The investigators will also study finer-scale nested-model output downscaled from selected case segments from GCM climate change simulations. Changes in the frequency, orientation, intensity, or seasonality of key circulation patterns and local and regional inversion-related characteristics will be used to infer how the frequency and intensity of low-level inversions might also change.

The U.S. EPA has sponsored research contracts with Dr. Harley of UC Berkeley and Dr. Kleeman of UC Davis to assess the consequences of global change for air quality in California. The results of these research contracts will be available for ARB's climate change projects. Dr. Harley's research project includes three major tasks: (1) air quality modeling in conjunction with online sensitivity analysis techniques to quantify how ozone responds to changes in key factors such as anthropogenic and biogenic emissions, (2) process-level analysis of the impacts of climate-related variables on atmospheric chemistry, biogenic and anthropogenic emissions, and atmospheric transport and mixing, and (3) integration of the results of the first two tasks into an overall assessment of the impacts of climate change on air quality. What is the relation of this to scenarios project?

Dr. Kleeman's research project will combine innovative land use forecasting models, water constraint models, travel demand models, emissions models, and a source-oriented air quality model into a modeling system with feedback loops to predict future emissions and associated air quality impacts. The modeling system will be used to assess the sensitivity of emission inventories to future policy scenarios, including land use,

transportation investments, technological innovations, air quality regulations, and agricultural practices in the SJVAB in the year 2030.

The temperature correction factors for light-duty gasoline vehicles (LDGVs) have not been updated since the early 1990s. The current plan is to conduct research in this area as an in-house project at the ARB Haagen-Smit Laboratory in El Monte, California. In addition, ongoing studies are investigating the detailed relationships between temperature—including temperature extremes—and patterns of electricity consumption and demand in California. Climate change is driven not only by anthropogenic activities, but also by biosphere processes that change in conjunction with climate. Emission of VOCs from vegetation may be particularly sensitive to changes in climate and may play an important role in climate forcing.

Using gridded meteorological information, ARB staff will perform emission modeling simulations to adjust temperature-sensitive components of biogenic emissions inventories. The results of these studies need to link with on-going CEC funded research projects on plant species mitigation. Also, once results from these various projects are obtained, the changes in ambient ozone and particulate matter could be linked to an epidemiologic/economic model to calculate the health costs of changes in air pollution.

Products:

- A paper on air quality impacts (Mike Kleeman)
- A paper on historical variability of low-level inversions in California (Iacobellis and Cayan).
- A paper on projected changes in the variability of low-level inversions in California (Iacobellis and Cayan)
- A paper on air quality impacts (Harley)
- A paper on estimated changes in emissions by 2030 (Kleeman)
- A paper on potential changes of air pollutant emissions from cars and vegetation
- A paper on overall economic impacts

Forest Resources and Forest Fires

An estimate of how commercially-important tree species would fare under climate change is needed as an input to the economic analysis. Lee Hannah (Conservation International/UC Santa Barbara) will perform these simulations as part of his on-going PIER effort. He will work with economists from UC Santa Barbara to update/improve the sectoral economic impact study prepared as part of the 2003 PIER report (Mendelsohn 2003). Both market and non-market economic impacts will be estimated.

Professor John Battles (UC Berkeley) will enhance the study his group prepared for the 2006 report by performing a much more detailed evaluation of climate change impacts on managed pine forests. Prof. Battles and his group will perform a full-blown growth and yield assessment across the gradients in the Sierra Nevada, with key links to the economic implications and an analysis of the potential for adaptation by planting

different species. The Sierra-based timber companies have expressed a strong interest in this study.

For forest fires we suggest commissioning a study by Tony Westerling updating/improving his 2006 paper and, perhaps, updating his Science paper (Westerling 2006) using California Department of Forestry (CDF) data. Some of the substantial improvements that would be implemented include: 1) using a much simpler, more elegant model specification with moisture deficit[4] as an explanatory variable, instead of using hydro-climatic variables (e.g., soil moisture, precipitation, etc.); and 2) estimating the risks associated with the fires that are responsible for much of the economic impacts. Under this proposal, Westerling would also perform an economic evaluation of the impacts.

Products:

- A paper on estimates of market and non-market impacts of climate change on the forest ecosystems in California
- A paper on climate change impacts on managed pine forests and potential coping strategies for land managers.
- A paper updating and improving Westerling's 2006 study on forest fires

Energy Demand and Hydropower under Climate Change

Larry Dale et al. will estimate water and energy demand for the residential sector using econometric relationships being developed under a new PIER project. They are using confidential household level data that, at one point in the future, PIER will combine with an urban growth model to estimate water and energy demand in a GIS framework. This work may provide the first well-developed estimates of the joint household demand for water and energy, which would be a significant advance.

Alan Sanstad and Guido Franco may be able to extend their analysis using hourly electricity and natural gas demand to estimate potential changes due to climate warming (Franco and Sanstad, 2006). In addition to using hourly data (instead of daily average data), they will use time series for the last 10 or more years to estimate changes in baseline demand of energy. They may also be able to expand the analysis to produce estimates that are robust against key uncertainties in both electricity demand and climate and meteorological variables.

Regarding hydropower generation, CALSIM and CALVIN will provide the needed information to estimate changes in generation from low elevation generation units. For impacts on high elevation units, estimated impacts would come from both the UC Davis group and from UC Berkeley (John Dracup) using different approaches. UC Davis is using historical monthly hydropower generation to estimate statewide impacts while UC Berkeley is performing detailed engineering-economic studies for certain systems (e.g., SMUD high elevation units).

[4] Potential minus actual evapotranspiration

Combining household and hydropower analyses may allow for the first set of integrated estimates of the costs of climate change impacts on the linked energy/water system at a fuller range of relevant spatial, temporal, and system scales, and the benefits of various adaptation options.

Products:

- A paper on potential changes in water and electricity demand under different climate scenarios using statistical relationships developed using confidential household level data
- A paper on electricity and natural gas demand using historical hourly state level consumption data
- A paper on impacts of climate change on hydropower generation (UC Davis)
- A paper on case studies of the potential impacts of climate change on two or more high elevation hydropower systems
- A paper discussing overall economic impacts in the energy sector.

Cross-cutting Studies

The following are studies that involve multiple disciplines or require substantial input from the different research groups that will be involved in the 2008 Scenarios Projects.

- Other Impacts and Adaptation Studies: We would like to consider releasing an RFP asking for proposals covering other impact areas such as summer and winter recreation, insurance, etc. delete this?
- Extreme events: The goal of this study is to synthesize and supplement research on extreme events in California. It will focus on the assessment of present and future changes in the likelihood of events similar in magnitude to historical events, and, to the extent possible, the likelihood of concurrent extreme events and events more intense than those observed historically.
- Potential for adaptation to climate change in an agricultural landscape in the Central Valley of California: The vulnerability of California agriculture to climate change is a function of many factors, including exposure to climate change itself, vulnerability to such changes, and the ability to respond and mitigate changes without losing future options. Adaptive capacity can increase options for successful reorganization and resilience to environmental change. To understand these options, an interdisciplinary perspective is necessary, involving both biophysical and socioeconomic sciences. A case study of potential adaptation to climate change in an agricultural landscape is proposed for Yolo County, due to its representative cross-section of a Central Valley agricultural landscape, which encompasses the floodplain of the Yolo By Pass, intensive cropland of diverse horticultural and field crops, upland grasslands and savanna of the Blue Ridge, as well as urban and suburban communities. The proximity to UC Davis research capacity, and a history of close connections between farmers, ranchers, and

institutions supporting agriculture and the local community, is another reason for this choice of location.

- Scoping Study on Environmental Justice Issues: This study will involve a person well versed in environmental justice issues. His/her role would be to prepare a paper identifying environmental justice issues that should be addressed in future assessment. However, the researchers involved in the 2008 assessment may want to start considering environmental justice issues in their own analyses.

Summary/Integration

Dan Cayan, Alan Sanstad, Amy Luers, Guido Franco, Bart Croes.

References

CA Department of Finance 2005a. Population Projections by Race/Ethnicity, Gender and Age for California and its Counties 2000-2050.
http://www.dof.ca.gov/HTML/DEMOGRAP/ReportsPapers/ReportsPapers.asp#projections

CA Department of Finance 2005b. Suggested Allocations of the Non-Hispanic Multirace Category for Use with Population Projections by Race/Ethnicity
http://www.dof.ca.gov/HTML/DEMOGRAP/ReportsPapers/ReportsPapers.asp#projections

Franco, G. , A. Santad (2006). Climate Change and Electricity Demand in California. California Climate Change Center. CEC-500-2005-201-SF.
http://www.energy.ca.gov/2005publications/CEC-500-2005-201/CEC-500-2005-201-SF.PDF

Grübler, A., O'Neill, B. C., Riahi, K., Chirkov, V., Goujon, A., Kolp, P., Prommer, I., and E. Slentoe. Regional, national, and spatially explicit scenarios of demographic and economic change based on SRES. Technological Forecasting and Social Change (in press). 2006

Lobell D.B., Cahill K. N., Field C. 2006. Historical effects of temperature and precipitation on California crop yields. Climatic Change. In press.

Landis J. et al. 2003, How We Will Grow: Baseline Projections of California's Urban Footprint through 2100. PIER Report.

Mendelsohn R. 2003. A California Model of Climate Change Impacts on Timber Markets. PIER Report.

Newmann J. et al. 2003. Market Impacts of Sea Level Rise on California Coasts. PIER Report.

PPIC 2005. California 2025: Taking on the Future. Public Policy Institute of California.
http://www.ppic.org/main/publication.asp?i=489

Theobald, D. M., 2005. Landscape Patterns of Exurban Growth in the USA from 1980 to 2020. E&S Home. Vol. 10, No. 1
http://www.ecologyandsociety.org/viewarticle.php?id=1390

Westerling, H.G. Hidalgo, D.R. Cayan and T.W. Swetnam, 2006: Warming and Earlier Spring Increase Western U.S. Forest Wildfire Activity. Science, 313, 940-943

Wilson T. et al. Baseline Scenarios for a California Energy Commission Study of the Potential Effects of Climate Change on California: Summary of a June 12, 2000, Workshop. PIER Report.

CEC 2003. Global Climate Change and California: Potential Implications for Ecosystems, Health, and the Economy (Publication # 500-03-058CF & Appendices). PIER Report.

Scope of Work
(Extracted from the original Contract)

Climate Monitoring, Modeling, and Analyses: Phase III
And
2008 Scenarios Impact and Adaptation Study

GLOSSARY

Specific terms and acronyms used throughout this work statement are defined as follows:

Acronym	Definition
BLM	Bureau of Land Management
CALVIN	California Value Integrated Network
CPR	Critical Project Review
GHG	Greenhouse Gas
GIS	Geographic Image System
IPCC	Intergovernmental Panel on Climate Change
MS	Microsoft
SLR	Sea Level Rise
SWAP	Statewide Agricultural Production Model
UCC.1	Uniform Commercial Code (Financing Statement)
VIC	Variable Infiltration Capacity
WA	Work Authorization
WEAP	Water Evaluation And Planning system

GOALS OF THE AGREEMENT

The goal of this Agreement is to improve scientific understanding of how climate is changing in California, improve capabilities of monitoring these changes, and to guide the development of climate projections for the State. The research described in this Agreement will provide guidance to the state on the steps that must be taken to adapt to expected environmental changes due to global warming. In addition, the research will describe the effects of climate change to the economy of California. The overall goal of the research is to inform ongoing and future climate change policy development and decision making. The final work product will be a scientific report to the Governor and the Legislature by the end of 2008.

OBJECTIVES OF THE AGREEMENT

The objectives of this Agreement are the following:

- Improve our understanding of how climate is changing
- Install monitoring stations in key areas in the state to monitor how climate is changing in California.
- Provide policy relevant information to state, regional and local climate change policy and planning efforts.
- Prepare a high quality scientific report for the Climate Action Team.

Task 2: Observe watersheds and mountain transects

Task 3: Archive and process California climate data

Task 4: Study San Francisco Bay meteorological and sea level conditions

The goal of this Task is to investigate sea level conditions on open coast and in the San Francisco Bay, and the combined effect of sea level and riverine runoff.

The Contractor shall:

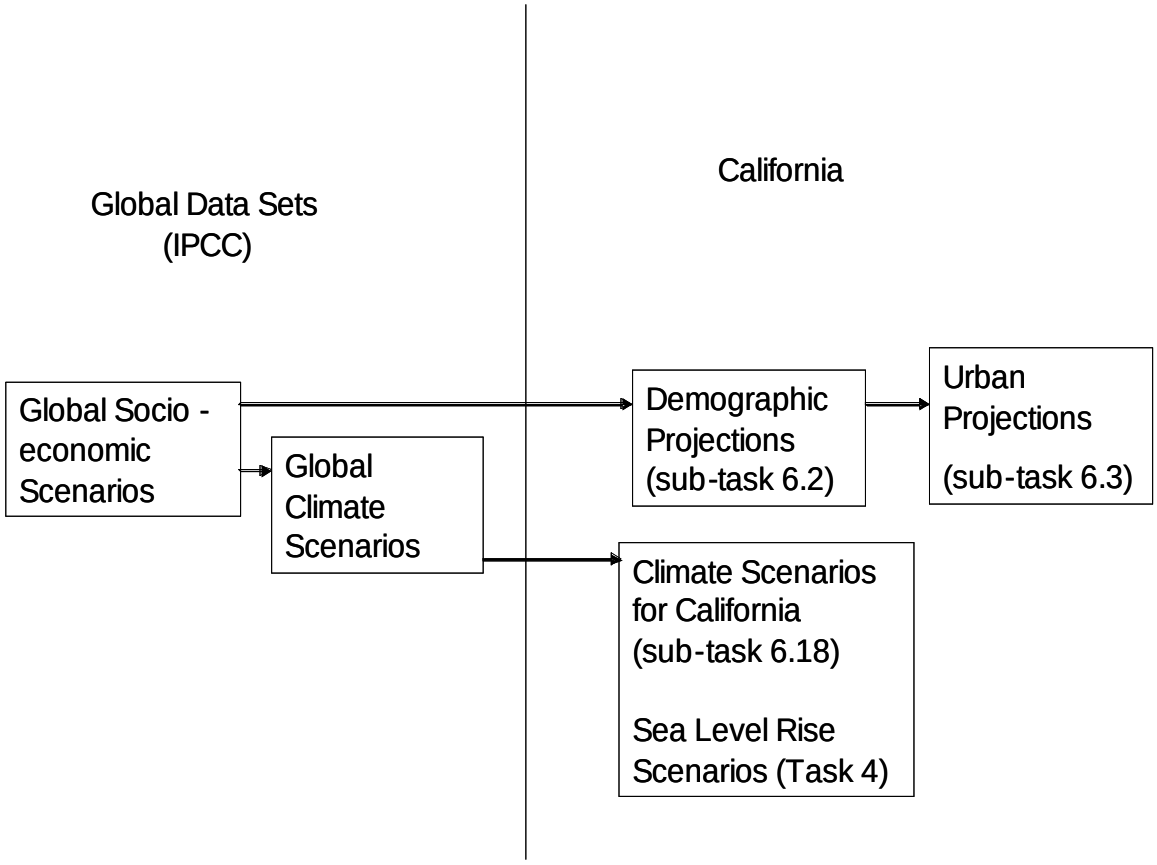
- Investigate flood mechanisms and changes in flood frequency of coastal and Sierra watersheds, including an evaluation of atmospheric circulation changes.
- Produce a Water Level Extremes Technical Paper. This paper shall include, but not be limited to, the analysis of observed water level extremes in the San Francisco Bay and Sacramento-San Joaquin Delta region, and include the effects of both sea level rise and freshwater flooding.
- Produce web-accessible Interactive Maps of maps of shoreline water level exceedance frequencies, corresponding to critical heights such as storm drain weirs in San Francisco, and a projection of changes in Delta levee overtopping potential. Scripps will maintain these maps for the duration of this Project.

Task 5: Study extreme temperature and precipitation events

Task 6: Prepare the 2008 Scenarios Project

The goal of this Task is to produce the different studies that are needed to produce the 2008 scientific report on impacts and adaptation that are needed to comply with Executive Order S-3-05 (p2).

For the 2008 Scenarios Project, the research team will develop population and urban projections that are in general agreement with the global scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). These global IPCC scenarios are socio-economic scenarios for the Earth as a whole. The research group will also develop climate and sea level rise scenarios for California that are compatible with the IPCC scenarios. Each IPCC scenario is linked to a global climate scenario which will be downscaled to the California region (see the figure below).



The research team will use the demographic and urban projections and the climate and sea level rise scenarios for California in their impact and adaptation studies.

Unless otherwise specified, all Papers and Reports prepared under this task shall:

- Require a first and second draft prior to the final paper or report. Both drafts will be prepared in accordance with the requirements in Task 1.5.
- Include an Executive Summary for policy makers, describing the implications of the research for California climate change policy.

SubTask 6.1: Study projected California demographic impact

The goal of this Task is to develop population and household projections for California and its counties that reflect certain IPCC scenarios.

The Contractor shall:

- **Per TAC input, d**evelop population and household projections for California and its counties to 2100. The projections will include age, gender, ethnicity, and national origin. A cohort component model will be used in which the population is aged over time by applying mortality and migration rates.

- Develop population projections for every five years from 2005 to 2100. Existing national and global population projections will be used to estimate the size of populations that are the source of migrants to California. Past trends in migration, fertility, and mortality rates in California will be used to develop future rates, with some adjustments made to reflect selected IPCC scenarios.
- Correlate, to the extent possible, population projections with data on predicted changes in water supply, land use and energy availability due to climate change in California.
- Use alternative assumptions (e.g., immigration rates to California) to develop several series of population projections, providing plausible ranges of future population change.
- Incorporate to the extent possible this work into the projections work done in other Tasks, including land use forecasts.
- Prepare a Projections of California Demographics Report which analyzes and summarizes the work performed in this task. This Report does not require an Executive Summary.
- Compile a Population Projection Database consisting of population projections disaggregated by year, county, age, gender, ethnicity, and national origin.

SubTask 6.2: Study projected California housing density impact

The goal of this Task is to develop a spatial database of allocated population, specifically housing stratifications that reflect the selected IPCC scenarios in California.

The Contractor shall:

- **Per TAC input,** develop public domain housing density data and maps at the sub-county level to reflect population projection scenarios. The housing density maps will reflect the population changes from 2000 to 2100 at the sub-county scale and the expected housing type.

- Generate a series of spatial databases in native GIS form that will reflect the location of population and households under each IPCC scenario. The spatial data will be developed at 5-year intervals and will take into account work previously performed by Landis et al. (Appendix III. *How We Will Grow: Baseline Projections of California's Urban Footprint through 2100*, http://www.energy.ca.gov/pier/final_project_reports/500-03-058cf.html) and others. Spatiotemporal interpolation methods will be drawn from readily-available methods.
- Prepare a California Housing Density Projection Report which analyzes and summarizes the work performed in this task.

SubTask 3: Study water management impact and adaptation

The goal of this Task is to expand the geographic coverage of available WEAP (Water Evaluation and Planning) applications by focusing on developing an application of the west side of the San Joaquin Valley. This application will focus on representing the combined use of scarce surface water and available groundwater in a manner that reflects the hydrologic realities of this system where a saline unconfined aquifer is managed via the use of drains and an underlying confined aquifer is managed as an agricultural water supply. The model will be used to study potential impacts and adaptation options.

The Contractor shall:

- **Per TAC input,** develop and implement a methodology within the WEAP model to approximate the hydrologic effects of agricultural drains.
- Configure appropriate WEAP catchments of the western San Joaquin Valley.
- Develop a representation of the San Luis Reservoir in WEAP.
- Link the WEAP application of the western San Joaquin Valley to the existing Sacramento Valley application.
- Incorporate the economic analysis provided by UC Berkeley under Agreement (PIER Contract #500-99-013, Work Authorization BOA-119 Amendment 2) with the Energy Commission in the WEAP model. These economic analyses will focus on representing the drivers and controls on groundwater management in the region in a manner that allows for the simulation of future cropping patterns, water use patterns, and potentially agricultural land retirement patterns.
- Test, replicate, and validate until acceptable by the TAC the version of the WEAP model which incorporates (info from above) to make sure it corresponds with historical conditions.
- Conduct at least three studies using the climate change scenarios developed in this Project, using the socio-economic scenarios developed under Task 6.2 and the corresponding urban, suburban, and exurban projections under Task 6.3.
- Prepare a Water Management Adaptation to Climate Change Report which analyzes and summarizes the work performed in this task.

SubTask 4: Study water supply economics and management

The goal of this Task is to investigate potential adaptation strategies for the water system in California using a new version of the CALVIN (California Value Integrated Network) model, a public domain software, that now includes the following important enhancements:

- Improved representations of groundwater resources;
- Inclusion of penalty function for flooding events;
- Consideration of sea level rise effects on salinity in the Delta region; and
- Updated water conveyance inter-ties for Bay Area cities and the Tulare Basin.

The Contractor shall:

- Per TAC input, develop hydrologic inflows for the CALVIN model using the new climate change scenarios developed in this Project, and perform climate change runs using this data.
- Incorporate estimates of climate change on agronomic water demands and yields into economic value functions employed in the CALVIN model.
- Explore the costs of non-optimum responses of the water system imposing, for example, limited water markets that may be more politically feasible in an attempt to explore less optimum solutions that may be nevertheless more politically viable.
- Produce agricultural water delivery scenarios for different parts of the state for post-processing by other models, including but not limited to, the Statewide Agricultural Production Model, in this Project,
- Coordinate this work, with the work done with the WEAP model under Task 6.4 (for example) suggesting adaptation strategies that could also be explored with the WEAP simulation model.
- Coordinate this with the studies on agricultural impacts.

- Use the climate change runs to study the potential impacts of climate change on water resources and investigate potential adaptation options.
- Estimate the potential impacts of climate change on high elevation hydropower units using the climate scenarios developed by Scripps.
- Produce a paper on the use of CALVIN. This report shall include, but not be limited to, discussions about potential impacts and adaptation options. This report need not include an Executive Summary.
- Produce a Climate Change Impact on High Elevation Hydropower Unit Paper. This report shall include, but not be limited to a discussion about the potential impacts of climate change on high elevation hydropower units and the identification of potential coping strategies.

SubTask 5: Study sea level impact in the San Francisco Bay

SubTask 6: Study forest ecosystem impact

The goal of this Task is to conduct two studies that will incorporate a multi-faceted biological and economic model to capture the most important drivers of the changes in timberland and forest ecosystem services.

The Contractor shall:

- Per TAC input, conduct a California Timberland Study evaluating the potential impacts of climate change on California Timberlands. This Study shall build on the approach taken by Mendelsohn (2003, Appendix XII. A California Model of Climate Change Impacts on Timber Markets, http://www.energy.ca.gov/pier/final_project_reports/500-03-058cf.html).

  The economic modeling conducted in this Study will examine the dynamics of land use change, land values, and changes in landowner management priorities. In addition, this Study will assess the policy implications of shifting timber species distributions and timber values on public lands. The analytical framework of Mendelsohn's approach will be expanded to account for changes in landowner management objectives and possible policy levers by, without limitation:
    - Incorporating information from multiple biological models, particularly a species-based model of biological effects of climate change;
    - Using estimates of land use change available within the biological model to improve on previous assumptions of no change in land use;
    - Encompassing both private and public timberlands, which considerably expands of the previous focus on private timberland only;
    - Using more accurate and detailed timber price data by using price data for each timber species at the county level, as opposed to the statewide average approach used in previous studies;
    - Accounting for uncertainty in the biological model, economic model, and landowner management decisions through consensus modeling, stochastic optimization, and other techniques; and
- Prepare a Climate Change Impacts on California Timberlands Paper which analyzes and summarizes the results of the California Timberland Study.
- Conduct a California Forest Ecosystems Services Study. In the course of this Study, the Contractor shall:

    - Assess potential impacts on forest ecosystem services that result from changes in the area, distribution, and values of private and public forests in California. These estimates will be derived from literature, current research, and estimates comparing current species composition and land use demand with species composition and land use demand calculated by the biological model for different climate scenarios.
    - Assess current methods for valuing forest ecosystem services and their applicability to the forest ecosystem in California.
    - To the extent of which data are available, consider the impacts of a greenhouse gas cap and trade system, with forestry offsets, on both timberlands and forest ecosystems in their studies.
- Prepare a Climate Change Impacts on California Forest Ecosystems Services Paper which analyzes and summarizes the results of the California Forest Ecosystems Study.

SubTask 7: Develop forest production models

The goal of this Task is to perform a case study about the potential impacts of climate change on forest production and the identification of potential adaptation options. Highly productive and intensively managed conifer forests occur at the lower and mid-montane zone of the Sierra Nevada and southern Cascade mountain ranges in California. These forests provide carbon neutral construction wood and biofuels that contribute to long-term sustainability. The mills, logging and transportation infrastructure that these forests support are key components of the economic systems necessary to adapt to climate change. The developed models will incorporate uncertainty in measurements, ecological processes, methods, and projected climate scenarios, providing not an answer but a range of answers with a defined level of confidence.

The Contractor shall:

- Per TAC input, update the forest growth models known as Forest Vegetation Simulator (FVS) for pine/mixed conifer timberlands.
- Develop models from data for specific sites that represent the range of timberlands, climates, and associated economies across the Sierran gradient.
- Generate climate-sensitive models that can interact with the Forest Vegetation Simulator, a nation-wide forest simulation provided by the United States Forest Service.
- Link scenarios of forest growth and mortality to relevant economic ramifications. For example, the higher value of the pine species, especially compared to the lesser value of cedar or fir, remains a major determinant of overall projected financial viability of potential adaptive strategies. This viability will depend on the economic value of pre-commercial and commercial thinnings as well as other biomass that increases the fire risk to existing stands. These sorts of questions can be addressed by using the ecological outputs to drive economic models like the USDA Forest Service's BioSum software package that links local inventories to facilities via regional transportation models.
- Assess the impact of a cap and trade market, with forestry offsets, on forest production.
- Prepare a Forest Production Models Report which analyzes and summarizes the work performed in this task, and additionally includes discussion on potential adaptation strategies.

SubTask 8: Study climate change impacts on wildfire

The goal of this Task is to improve the studies of Westerling and Bryant's work on fire modeling and loss modeling (2006; 2007). Recent work has suggested that wildfire in California's forests and related property losses will increase substantially with climate change.

The Contractor shall:

- Participate in a meeting/conference call with project staff working on demographic and development scenarios to discuss how to best coordinate and integrate their products into models for property losses due to wildfire. Based on the results of this meeting/conference call prepare, if needed, a revised description of the technical activities to be undertaken.
- Refine and evaluate the fire risk models used in the projections of Westerling and Bryant (2006 & 2007). The current models are empirically based on 1980-1999 downscaled climate data (temperature and precipitation) and simulated hydrologic data (soil moisture). The contractor will explore whether the use of products from new downscaling techniques and hydrologic simulations, as well as new hydrologic variables (Moisture Deficit), results in significant changes in model predictions.
- Refine and evaluate property loss models used in the projections of Westerling and Bryant (2006 & 2007). These models include estimates of property values based on US Census and county assessor parcel data, and estimates of damage ratios (percentage of threatened structures lost in a wildfire). The contractor will evaluate whether more detailed parcel data will improve property value estimates. The contractor will refine and evaluate models for estimating damage ratios as a function of housing density, fire risk, vegetation type and topography.
- Incorporate development scenarios in property loss estimates due to wildfire. Westerling and Bryant assumed the level and spatial distribution of future property values were fixed at the 2000 census. The contractor will evaluate the impact of incorporating a range of different development scenarios on property losses due to wildfire under a range of urban development scenarios.
- Evaluate the impact of changes in wildfire risks due to climate change on suppression costs. The contractor is developing models of fire suppression costs for Forest Service and Bureau of Land Management (BLM) budgeting and planning through the peak of the fire season in California and the western US that are driven by fire risk models and spatial variability in historical cost data. The contractor will apply these suppression cost models to fire risks modeled under climate change scenarios to estimate the effect of climate change on fire suppression costs in California. These results will assume that fire management strategies and resources do not change significantly over the study period (i.e., they will project the effects of climate change on costs given current fire management).
- Assess coping strategies in the form of different development patterns, and express their benefits in terms of property losses relative to a reference scenario.
- Prepare a Climate Change Impacts for California Wildfire Report which analyzes and summarizes the work performed in this task.
- To the extent possible, incorporate fire suppression strategies under development by the California Department of Forestry and Fire Protection,

SubTask 9: Study end-user impact of extreme events

The goal of this Task is to improve existing research on the end-user impact of extreme events in California. It will focus on assessment of present and future changes to end-users (such as the power generation and agricultural sectors) in the likelihood of events similar in magnitude to historical events, and, to the extent possible, the likelihood of concurrent extreme events and events more intense than those observed historically.

The Contractor shall:

- Examine and synthesize the work of the various research groups that are conducting impacts work related to extreme events in California. The research team will:
    - Rely on the TAC to define what constitutes an "extreme event" in each impact sector.
    - Coordinate with these groups to utilize their most recent relevant results, with an eye to judging the likelihood of extreme events of the same magnitude as key past events and how that might change in the future, ideally related in the same way as past impacts work in California to higher and lower emissions scenarios.
    - Rely on these groups to identify appropriate historical events to use in the analysis. This coordination may require an iterative process between the research team and each impacts group to acquire or generate needed data.
- Assess the likelihood of concurrent extreme events, relying to the extent possible on the results of the first task. Specifically, this study shall utilize:
    - historical data,
    - model simulations of historical conditions and future projections, and
    - scientific judgments of relevant experts on the ranges and likelihood of future climate change that might alter the occurrence of extreme events, interactions between extreme events, and the likelihood of concurrent extreme events.
- Prepare a Changes in California Current and Future Extreme Events Report which analyzes and summarizes the work performed in this task.

SubTask 10: Study Central Valley agricultural adaptations to climate change

The goal of this Task is to study potential adaptations to climate change in an agricultural landscape. The study will focus on Yolo County due to its representative cross-section of a Central Valley agricultural landscape, which encompasses the floodplain of the Yolo Bypass, intensive cropland of diverse horticultural and field crops, upland grasslands and savanna of the Blue Ridge, as well as urban and suburban communities.

The Contractor shall:

- Assemble a group of scientists to form an interdisciplinary research team to investigate different issues contributing to sensitivity, vulnerability and adaptation to climate change in Yolo County, e.g., agricultural ecology, geographic information systems, hydrology, agricultural and resource economics, environmental policy, political science, and community development, and work with an advisory group to prioritize key issues for detailed study.
- Describe the current agricultural landscape of Yolo County using a variety of data sets and approaches that include present and historical land uses, agricultural commodities and production issues, income and livelihoods, relevant policies and institutions, population growth and urban and suburban issues related to agriculture.

- Develop a series of potential scenarios for adaptation to climate change in Yolo County, based on input from consultants, collaborators, and from similar projects in other Mediterranean climates. These scenarios will then be used to explore plausible outcomes and the vulnerability and adaptive capacity of the current agricultural landscape of Yolo County to climate change using regional outcomes from climate models for California, published literature, and information obtained from consultants from various stakeholder groups, including public agencies and nongovernmental organizations.
- Collaborate with other research groups in the 2008 Scenarios Project to integrate their modeling on crop production and economic outcomes into projections for Yolo County.
- Provide recommendations to the TAC on how to consider the role of public institutions, policies, regulations and laws on determining scenarios for adaptation to climate change, e.g., the Endangered Species Act.
- Evaluate the potential resilience to climate change for various types of land uses and landscape types, and for various segments of society, with an emphasis on tradeoffs that occur in relation to agricultural sustainability, i.e., agricultural production, environmental quality and social well-being.
- Prepare a Central Valley Agricultural Adaptation Paper which analyzes and summarizes the work performed in this task.

SubTask 11: Study effects of climate change on Central Valley crop production

The goal of this Task is to use an ecosystem modeling approach to link land use, soil and climate data, and predict changes in crop yield in response to changes in the average and the variability of the temperature and precipitation regime in California. Predicting field crop yields in the coming century requires complex ecosystem modeling that integrates crop growth, nutrient dynamics, hydrology, management and climate.

The Contractor shall:

- Characterize the Central Valley by dividing this region into 100 square kilometer grid cells, assigning to each cell soil and climate condition within a GIS framework, and identifying for each grid cell the proportion of crops cultivated. The crops included will be the main field crops, rice and vegetables, orchards, and vineyards. This approach will allow the contractor to simplify the regional modeling, integrate it with other available and forthcoming GIS databases, such as Scripps weather data and the California Value Integrated Network (CALVIN) water availability model.
- Determine soil and land use distribution, using the best sources of data available including land use information from:
    - United States Department of Agriculture, National Agricultural Statistics Service (data at county level, and available every year),
    - Agricultural commissioners (data available for most counties per township-range-section and available most years),
    - Department of Water Resources (data per field, but only available for selected counties and selected years),
    - The Soil Survey Geographic Database from the Natural Resources Conservation Service, and
    - Grid or county-level weather scenarios under climate change using the climate scenarios produced for 2008 Scenarios Project.

- Simulate the effects of climate change for each crop per grid cell. This simulation will utilize the DayCent model, an ecosystem model which has already been calibrated by the contractor for California conditions.
- Estimate uncertainties around crop responses coming from:
    - Uncertainties around changes in climate,
    - Uncertainties due to year-by-year variations (e.g. due to extreme weather events such as heat spells), and
    - Uncertainties around soil and management input variables.
- Conduct scenario analyses to elucidate how growers could adopt by changes in management (i.e. changing planting data and fertilization regime).
- Estimate the effect of water availability using at least two scenarios:
    - Availability of water for irrigation is non-limiting, and
    - Water availability is limited as predicted by the CALVIN model or similar models.
- Prepare a Climate Change on Crop Production in the Central Valley of California Paper which analyzes and summarizes the work performed in this Task.

SubTask 12: Study economic impacts of climate change and adaptation options in the agricultural sector

The goal of this Task is to explore potential economic impacts of climate change and adaptation options in California's agricultural sector.

The Contractor shall:

- Per TAC input, configure the SWAP model in a way that could be used for climate impacts and adaptation studies. SWAP is a computer model that simulates transport of water, solutes and heat in variably saturated top soils.
- Use the climate scenarios and the water restrictions provided by other models (e.g., CALVIN and WEAP) to estimate impacts and adaptation options.
- Use the newly develop crop yield findings generated by Lobell et al. in the SWAP model.
- Prepare a Climate Change Economic Impact and Adaptation Options Paper which analyzes and summarizes the work performed in this Task.

SubTask 13: Study economic impact on agriculture using econometric techniques

The goal of this task is to estimate the effect of the PIER climate change scenarios (see the description at the start of task 6) developed throughout this Project on California agriculture. The effect will be in terms of changes in the value of farm output at the county level, holding prices constant. To the extent data permits, effects will also be determined at the sub-county level.

The Contractor shall:

- Estimate the effect of weather and climate on California agriculture using the profit function approach. At a minimum, this will be performed at the county level. Efforts will be made to extend the data to the ZIP code level, using Census of Agriculture data.
- Apply the climate change scenarios being generated by Scripps for this Project to the estimated relationship to determine the effect of the projected climate change on the value of the state's agricultural output, at least at the county level.
- Prepare a Climate Change Impact on California Agriculture Paper which analyzes and summarizes the work performed in this Task.

SubTask 14: Study economic impact on Southern California beaches

The goal of this Task is to examine the impact of beach loss and erosion due to climate-driven sea level rise (SLR) in Los Angeles and Orange Counties.

Sea level rise (SLR), driven by global climate change, is likely to cause severe erosion and even the total loss of many low-lying beaches in California. Reduced beach width and total beach loss are known to result in substantial losses of economic value to beach goers, lost revenues for beach-related businesses, and even reductions in home values. While costly beach armoring may protect homes, only beach nourishment can replenish sand lost to erosion. Even beach nourishment may not be feasible for small pocket beaches that could be completely or seasonally flooded due to sea level rise.

The Contractor shall:

- Modify an existing model of beach recreation for southern California (Hanemann, Pendleton, and Mohn, 2006, "Southern California Beach Valuation Project") using newly acquired data on beach size being developed for an in-progress project on the economic value of beach nourishment to estimate the potential economic impact of beach erosion and beach loss in Southern California's Los Angeles and Orange Counties due to sea level rise. Specifically, for a variety of SLR scenarios this task will estimate changes in:
    - Day use attendance at beaches in Los Angeles and Orange County,
    - The economic value (consumer surplus) enjoyed by day use beach goers, and
    - Expenditures by day use beach goers.
- Develop estimates of the potential cost of beach nourishment that may be employed to stem the loss of beach sand at vulnerable beaches in these counties.
- Estimate the potential net economic impacts on beach recreation of sea level rise for scenarios that also include adaptation to sea level rise using the above estimates of beach nourishment and the potential economic impacts of beach loss.
- Prepare a Climate Change Impact on California Beaches Technical Paper which analyzes and summarizes the work performed in this task.

SubTask 15: Study impact of heat waves on mortality and morbidity

The goal of this task is to complete three studies relating temperature and heat waves to mortality and morbidity in California.

The Contractor shall:

- Extend a study the contractor conducted for PIER on temperature-mortality research by identifying susceptible subgroups in the same nine California counties, using the same data set as a previous study submitted to PIER (Climate Change Impacts: Potential Impact of Height Temperatures and Air Pollution on Public Health, UC BOA-118-03).
- Compare mortality risk by age group (focusing on infants, young children, and the elderly), ethnicity, gender and education level.
- Conduct a study of temperature and mortality for the same six California counties that provided preliminary mortality data over the heat wave period in July 2006.
- Compare the result from this study with that of UC BOA-118-03, which estimated mortality risk in the warmer months from 1999 to 2003 without any clear heat waves.

- Develop a time-series study using statistical regression techniques using daily mortality counts from all causes and mean daily apparent temperature. Minimum and maximum daily apparent temperature shall also be considered. This effort will characterize the extent of the non-linearity of the dose-response estimate and whether empirical estimates based on non heat wave periods underestimate the effect of temperature extremes.
- Examine the association between temperature and morbidity using data from several California counties in the warmer months of 1999 to 2004. Specifically, analyze hospital admissions for all causes, respiratory diseases, cardiovascular diseases, cerebrovascular diseases, and diabetes; and evaluate possible differences by age group (primarily infants, young children, and elderly), ethnicity and gender.
- Prepare a Climate Change Impact on California Heat Waves Paper which analyzes and summarizes the three studies and associated work performed in this task.

SubTask 16: Study future greenhouse gas (GHG) emission scenarios

The goal of this Task is to produce a report on future greenhouse gas emissions scenarios that includes usable probabilistic projections of emissions and radiative forcing pathways suitable for use in modeling future California climate. This report and the projections it contains will be based on both existing scholarly research – including methods for creating distributions of likely radiative forcing pathways – and a new survey of expert opinion. The report will also contain an appraisal of the robustness of the results and their implications for further modeling and policy analysis.

The Contractor shall:

- Design survey questions to collect useable information in a variety of forms to account for the fact that not all of the experts likely to be surveyed believe that it is possible to represent future emissions projections probabilistically in a straightforward manner. For example, it will be necessary to devise protocols for eliciting expert opinion of the likelihood of the implementation of climate policy and the effectiveness of that policy in reducing emissions.
- Survey at least ten leading researchers with expertise regarding emissions scenario design, socioeconomic development, energy modeling, and trends in key regions using the survey questions designed above.
- Improve on a public domain working model previously developed at Stanford University which produces probabilistic estimates of pathways for radiative forcing, based on assumed distributions of parameters for the radiative forcing from aerosols and other non-carbon dioxide gases, and the future behavior of carbon sinks.
- Develop two sets of probability scenarios for future GHG emissions. One scenario will base its data upon “business as usual” projections developed by IPCC where the status quo is maintained. The second scenario will be based on aggressive GHG emission reductions, pursued beyond those outlined in the Kyoto Protocol. This second set of scenarios will be obtained from publications in the peer-reviewed literature and from direct contacts with the groups developing these new scenarios. For example, the US Climate Change Science Program recently developed new emissions scenarios that could be used under this contract. The TAC (see subtask 6.0) will assist the Commission Project Manager in selecting these new sets of scenarios.
- Prepare a report on Future GHG Emissions Scenarios which analyzes and summarizes the work performed in this task. This report shall include but not be limited to usable probabilistic projections of emissions and radiative forcing pathways suitable for use in modeling future California climate, and the two probability scenarios outlined above.

SubTask 17: Downscale statistical techniques and hydrological modeling

The goal of this Task is to assist the TAC with the generation of climate change scenarios using the statistical downscaling technique used for the 2006 Scenarios Project and the Variable Infiltration Capacity (VIC) model, a public domain system, to translate these climatic scenarios into hydrologic outputs.

The Contractor shall:

- Downscale the selected outputs from global climate models to the California region using the same statistical downscaling technique used for the 2006 Scenarios Project.
- Compare the results of the prior statistical downscaling technique with the new statistical technique developed by Scripps for PIER ("Downscaling Daily Precipitation and Temperature Fields Over the US with Constructed Analogues." Draft PIER Report)
- Generate hydrologic scenarios using VIC.
- Provide the data to the different researchers working on this Project.
- Prepare a Statistical Downscaling Techniques and Hydrological Modeling Paper analyzing and summarizing the work performed in this Task.

SubTask 18: Study impact of climate change on California agriculture and adaptation

The goal of this Task is to improve the study of Lobell et al. (2006. "Impacts of future climate change on California perennial crop yields: Model projections with climate and crop uncertainties") and perform an adaptation case study. Recent work has suggested that California's multi-billion dollar perennial crop industry may sustain significant yield losses due to climate change over the next 50 years.

The Contractor shall:

- Refine and evaluate the crop models used in the projections of Lobell et al. The current models are empirically based on 1980-2003 data aggregated to the state level. The contractor will explore whether the use of data prior to 1980, as well as data at the county scale, results in significant changes in model predictions.
- Compare the predictions of the empirical models with those from more process-based crop models, such as used in assessments of future changes in water demand or biogeochemical fluxes. The results will provide a measure of the sensitivity of conclusions in the various studies to the type of crop model used.
- Evaluate the economic impacts of yield losses collaborating with the sectoral economic study described in Task 6.14. The contractor will collaborate as needed with the researchers providing work in Tasks 6.13 and 6.14 to translate yield scenarios into changes in crop prices and overall production. This will involve simulation of the various adjustments in crop prices, management practices, crop area, and crop substitution driven by yield changes.
- Perform an adaptation case study for almonds. Current model estimates do not consider adaptation efforts of growers, in part because of the long life-span of perennial crops. However, identifying adaptation options is critical not only for accurate projections, but for enabling growers to cope with expected climate change. As a case study of adaptation, the contractor will focus on almonds, one of the most valuable crops in California and almost certain to be affected by warmer temperatures. Specifically, the contractor will:

    - Identify the relevant characteristics of the major almond varieties, such as their chilling unit requirements.
    - Model the change in chilling units through time at different locations based on climate projections, and evaluate the relative suitability of the different varieties.
    - Identify varieties that become more or less suitable as climate warms
    - Measure the potential risks of changing varieties. For example, growers that switch to varieties better suited to warmer temperatures may risk yield losses in the current climate.
- Prepare a California Crop Report which analyzes and summarizes the work performed in this Task.

SubTask 19: Other Studies

The goal of this Task is to cover one or more studies that the Scenarios Subgroup may decide to fund to complement the studies listed in the previous subtasks. For the PIER work for the 2006 Scenarios Studies some limited funds were available for potential new studies that could be uncovered during the execution of the overall research. This approach proved to be extremely useful.

The new studies will be mostly on economic impacts and adaptation options. Some of the studies that may be considered include, for example, an assessment of the impacts of sea level rise on coastal infrastructures.